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The body probably understands

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Learning probability can pose difficulties for students at all levels. Based on studies indicating that conducting probability experiments with concrete means can encourage students to develop an understanding of probability we tested the feasibility of learning abstract concepts in complex mathematics by applying embodied learning through movement-based games. Following a careful analysis of probabilistic concepts, a stratified movement class was structured according to the graded construction of the concepts. These were studied as metaphorical images for concrete situations experienced in the body. The findings of the study confirm the hypothesis that the achievements of middle school and high school students who learn probability through one movement lesson will meet the requirement of a standard achievement test. Furthermore, the degree of interest, curiosity, and satisfaction of students, who learned probability in this way, was substantial.

Keywords: Game-based learning, kinaesthetic methods, experiential learning, embodied learning, learning through movement.

Background and theoretical framework

Questioning the feasibility of learning abstract concepts in mathematics in middle and high school was based on the complexity of the concept of probability and the limited achievements of teachers teaching it by conventional means. The basic premise was derived from the embodiment theory developed by Lakoff and Johnson (1980), which implies that all learning begins with the body, and from the theory of multiple intelligences, which emphasizes that one intelligence can be used to learn concepts in the field of another intelligence.

Difficulties in teaching probability

Learning probability is based on familiarity with complex concepts, such as variation, randomness, independence, inability to predict and uncertainty. These abstract terms do not have unequivocal definitions that can be explained in simple language or through an illustration, so dealing with creating meaning is not trivial and can only be reached after a continuous learning process.

Heitele (1975) points to the intuitive dimension in teaching mathematics and probability. In the case of randomness, he emphasizes, it is necessary to strengthen the intuitive understanding towards the formal teaching of the subject. Kuperman (2007) suggests teaching probability through discovery rather than as a formal set of rules.

It is evident, therefore, that there are inherent difficulties in teaching probability. These difficulties stem mainly from the formalistic teaching method that disconnects probability from everyday reality and ignores intuitive knowledge. To overcome these difficulties, one must first understand what alternatives can be offered.

Embodied learning as a possible solution - metaphors can act as a bridge to understanding

The theory of embodiment is based on the premise that cognition is anchored in the body and depends on its physical experiences. This theory rejects the philosophical separation between the body and the soul/consciousness/intelligence. According to this approach, the mind is an activity based on the relationship between the body, the environment, society, and culture.

According to the theory of embodiment, it can be assumed that movement/dance activity which structures a concrete concept as a metaphor for complex concepts in probability may prevent the confusion in studying and establish a layer of information that can be relied on in the development of probabilistic literacy.

Most metaphors are a mapping of a concrete concept, that is, a description of an abstract concept using a familiar concrete concept that lends its properties to the abstract concept. Conceptual metaphors rely on cross-domain mappings. They carry the inferential structure of the first domain into the second domain and make it possible to understand. Lakoff and Johnson's (1980) conceptual metaphor theory deals with abstract concepts, how they are constructed and how they are formed, claiming that many central cognitive processes, such as those concerning space and time, are expressed, and influenced by metaphors, and that many metaphors reflect the embodied experience of beings moving in the world. In education, metaphors can provide a powerful tool for teaching abstract concepts in terms of concrete models.

Metaphors, claims Duit (1991), help rebuild existing memory and prepare for new information. The use of exceptions and cognitive conflict, has great value as part of a conceptual change, which metaphors can produce and provoke. Involving a degree of imagination, metaphors help visualize abstract ideas and it seems that also link thinking and emotions and therefore may bridge the gap between the cognitive and emotional domains of learning.

In the field of mathematical education, there has been a growing recognition that metaphors are powerful cognitive tools that help to grasp or construct new mathematical concepts, as well as in solving problems effectively. Lakoff and Núñez (2000) view metaphors as an essential part of mathematical thinking; not just as auxiliary mechanisms used to visualize or facilitate understanding. Chiu (2000) determines that students can construct new mathematical concepts by metaphorical thinking that makes use of their intuitive knowledge. Students may also use metaphorical reasoning to connect mathematical ideas, remember them, understand mathematical representations, and perform calculations.

Research hypotheses: Embodied learning can improve probability comprehension

The first hypothesis of the study was that the achievements of middle school and high school students who learn probability through one movement lesson (2 academic hours), will meet the requirement of a standard achievement test. The evaluation of the students' achievements was carried out through an online multiple-choice test that included ten questions. The questions were collected from study materials approved by the Israeli Ministry of Education and validated matriculation questionnaires. The students answered the test questionnaire before the intervention, and at the end they were asked

to answer it again. The difference between the scores before and after the intervention can be regarded as evidence of an improvement in the knowledge of the studied concepts.

The second hypothesis was that the degree of interest, curiosity and satisfaction of students who learned probability in a movement class will be high and positive.

Methods rationale

The mathematics curriculum recommends teaching the chapter on probability in grades 8-9 in middle school. In practice, there are schools that give up probability studies altogether or those where the subject is taught through textbooks rich in tables into which data is poured, without understanding or connection to life and everyday contexts of probability calculations.

The methodology was constructed following thought-provoking recommendations on how to improve educational practice and lead to more effective learning. Cope and Kalantzis (2004) state that embodied learning focuses on the knowledge that students acquire when they use the body as a tool to build it. When referring to "body" in this context, they include the entire learner - the physical body, the senses, and the mind. Lindgren and Johnson-Glenberg (2013) describe this as the sensorimotor activity relevant to the subject to be reproduced and the emotional involvement of the participant in the whole process. Shapiro and Stolz (2019) argue that the emerging research agenda of embodied cognition can greatly contribute to educators, researchers, and policy makers. Their claims quote Nathan's (2012) position regarding the common mistake that control at the level of representations, in a specific knowledge domain, is necessary before it can be applied. A study by Glenberg (2008) examined these aspects in the teaching of mathematics and reading comprehension supporting the integrative approach to learning and emphasizing the importance of physical manipulation and abstract manipulation. In these two areas, the importance of the physical-tangible manipulation is evident before the importance of the abstract manipulation, because it is based on abstract symbols, i.e., letters and mathematical symbols.

Inspired by Abrahamson's (2012) research on embodied learning of probability, the following questions were asked:

- (a) what subjective notions of chance could potentially ground its formal analysis;
- (b) what sensations could give rise to these notions;
- (c) what source phenomena might evoke these sensations;
- (d) what framing activities with the source phenomena would evoke these sensations and notions;
- (e) what variants on standard mathematical forms might best accommodate students' perceptual reasoning; and
- (f) what discursive interaction would best support student coordination of these informal and formal views?

We distilled probabilistic concepts in the sequential order of learning as recommended by standard textbooks. Following conversations with math teachers, a preliminary stage of categorization and differentiation by properties was added. Seemingly simple, yet tricky, as students find it difficult to realize that an object may carry more than one property, which may pose an obstacle in the comprehension of probabilistic abstract concepts.

Lesson Plan Activities

In this study, 38 students from three semi-private schools took part in one lesson composed of:

1. A conventional test delivered in schools that teach probability through an online test. The questions at the different age levels were taken from valid study materials and matriculation questionnaires.

2. Activities:

A. **Categorization capabilities** - (what is inside the group and outside the group) – improving the ability to categorize as a starting point from which to connect previous knowledge for the construction of new knowledge. This first part of the lesson was also used for "Breaking the ice" and creating a comfortable space for movement.

In a circle, the students were asked to perform free movement accompanied by music. Next, they were asked to mirror a leader, isolating body parts – i.e., using **only one body part** at a time (hand, leg, head, etc.). The next stage was mirroring a leader moving in **different directions** – up, down, forward, sideways, diagonally. The following was mirroring an **emotion** conveyed by the leader's movement (fear, disgust, happiness etc.)

In pairs students were asked to analyze a partner's gestures layering two and then three categories: for example - move your head forward; and later move your arm up in expressing surprise. Following was verbal instructing the partner while layering two and then three categories. This phase assists the comprehension of the transition between concrete and verbal questions in math.

Conclusion of the first part was in a group game, making sure that everybody had a chance to experience categorization and adding a surprise dimension with a 'Simon Says' game, repeating the verbal dimension of layering categories and raising the focus level, having to determine whether to act on the leader's instructions (depending on if he literally says 'Simon Says' or not).

B. **Certainty, randomness, impossibility, and introduction of sample space.**

The class was divided into groups of 3 students. Each member was asked to conceive a simple movement and teach the others, memorizing it by repeating each movement 5 times. Following this the students were asked to perform the movements, following leader no. 1 and then no.2. This phase represents a certainty on the part of the followers, as opposed to randomness. No. 3 leaders were called aside and asked to perform a different movement than the one previously practiced. This caused confusion and embarrassment, a predicted emotional response, which was later defined as uncertainty and randomness.

As the activity evolved, a sample space of 3 movements and later 4 was defined. The students were then asked to take turns leading a sequence of their choice of the 4 movements accumulated in each group. Each student was asked what the chances are of seeing one of his movements.

The final part of this section was a class circle game, learning accumulatively all the groups' first 3 movements and realizing that as the sample space was enlarged, the chances of seeing each one's movement decreased.¹

C. Parallel independent events, complementary events.

The class practiced 4 different movements derived from an Israeli children's chant: hands up, on the head, on the shoulders, clap. The whole class then practiced playing 'red light, green light' for which the stopping positions were one of the 4 practiced positions.

The class was divided into groups of 4, movements were limited to 2, one student was on the finish line, one was acting as a reviewer and 2 students were playing. The reviewer's role was to record the actions of the players (according to a simple structured index). The students were then handed a 2*2 table representing the different possible variations and probabilities. Later, the 3rd and 4th movements were added, and respective tables of 3*3 and 4*4.

The tables that accompany the physical experience visually clarify the many possibilities that exist in the body and enable a link to a concrete experience. A gap is revealed between the actual observation and the findings of the table. This gap allows for a discussion of the difference between reality and mathematical calculation. While discussing the results, the concept of complimentary events was introduced.

3. Repetition of the conventional test from the beginning of the lesson.

4. Conversation with students and teachers about the teaching-learning experience.

Results and discussion

In this study, we tested the feasibility of teaching an abstract and complex concept in statistical mathematics through teaching a structured program that included movement games and dance, based on a stratified construction of metaphors. The research question was whether it is possible to assimilate the abstract concepts: randomness, certainty, uncertainty, sample space, event, and independent probability in a single meeting, built with great care and layered according to a gradual construction of the concepts studied.

The research hypothesis was that the achievements of students in the 8th grade, who learn probability through one movement lesson (2 academic hours), would meet the standard probability literacy test requirement and that their satisfaction level would be high. Due to logistical difficulties, students from higher and lower grades also participated in the study.

The methodology assumed that following MI theory, it is possible to develop a mathematical understanding of probability by relying on movement intelligence and build learning from the intuitive concept of probability to the mathematical concept. To learn the probabilistic concepts, the students interpreted the movement metaphorically. The use of conceptual metaphors ensured the

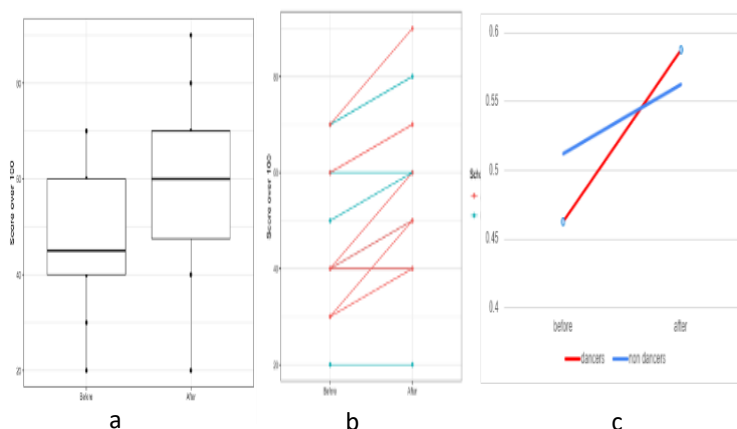
1 For a short video edit of this activity go to <https://www.youtube.com/watch?v=Diz7hgmrViE>

connection of the concrete occurrence to the development of meaning. The personally generated movement patterns assimilated the concepts into the body to establish an infrastructure of memory and knowledge about concepts from the world of probability.

Findings indicate embodied learning activity contributes to probability understanding

The test scores of the online questionnaire were calculated by 10 points for each correct answer, for a total of 100 possible points. A complete data analysis could not be carried out on the originally planned 8th graders, as they were very few and therefore was conducted for the results of 16 students: 8 11th grade students from a school in Zichron Yaakov and 8 10th-11th grade students from a school in Ashkelon.

The results were analyzed twice, once using the t test, which assumes that the observations were sampled from a normal distribution, and a second time using the Wilcoxon test. Assuming the test results reflect the level of experience of the students in physical/movement practices a test comparing averages was conducted. The results indicate a lower starting point for students with a dance and movement background and a more noticeable improvement than the higher starting point for students without a dance and movement background, whose improvement in their achievements is less significant. These results confirm another premise that the embodied learning method is more suitable for students who have previous experience in dance and who feel comfortable moving freely in class.



a- the average grades of the two classes increased between the first and second tests, scores are higher on average by 18 points out of 100; b- a noticeable difference between the two classes; c -a more pronounced improvement trend among students with a dance and movement background compared to students without it.

Figure 1: Test results before and after intervention

The results confirm the hypothesis that teaching based on a careful analysis of the studied concept allows learners to experiment with assimilating embodied learning and guarantees effective results in a short time.

A positive learning experience for students and teachers

The second hypothesis revolved around the degree of interest, curiosity, and satisfaction of students who studied a complex subject like probability in a movement lesson. The satisfaction assessment

was carried out through a discussion with the students and teachers at the end of the lessons and collecting responses from the video documentation.

The lesson aroused curiosity, enthusiasm, and active participation of the students and teachers. In the discussions, the students expressed wonder and longing to experience mathematics studies in a similar way in the future as well.

Student: Surprise, this lesson really surprised me. I didn't think there was a connection between mathematics and movement and now I saw that it was experiential for me, and I was also able to understand what was talked about.

The physical activity during a lesson in which the main topic is mathematics contributed to considerable enjoyment among the students and teachers. The ease and lack of formality contributed to creating an atmosphere conducive to learning. The graded construction of the activity included interpretive activities generated from their personal movement vocabulary and based on their previous knowledge. Learning the subject was accompanied by movement game-playing experiences, which assures embodiment, lowers the level of anxiety, enables concrete simulations, and contributes to the learning efficiency and satisfaction of the students.

Student: Although the subject studied was mathematics, this time, I felt very calm.

The desire arose to experiment with embodied learning in other fields.

Student: Wow, you can learn more subjects in mathematics by dancing, for example, geometry (accompanied by a movement of the arms that draws a right angle in space). My whole life will change if this happens.

The teachers' responses are characterized by reflective observation, expressing a fresh look at contents that have become routine and battered by formalistic teaching and a willingness to reexamine the way of teaching.

Teacher: How come they didn't think of this before? It seems to me that it would save us a lot of difficulty in teaching such complex subjects if there was such a structured program for all the problematic subjects.

Teacher: I admit that even I enjoyed it, and I'm ashamed to say, but it seems to me that this is the first time that I really, really, grasped this complex concept.

These reports from both students and teachers, even if not backed up by accurate statistical analysis, indicate that a non-standard, movement-based embodied learning process has the potential to raise the motivation to learn such a complex concept as probability, naturally and without fear. The analysis of probabilistic concepts and their metaphorical reconstruction by concrete movement activities contributed not only to the students' achievement improvement but also to reflective observations about nonstandard ways of learning.

Recommendations for future research

The research findings point to the advantages of this method. However, it is acknowledged that the size of the sample is very small and that several factors were not computed, such as the effects of each school, grade level and p-values (determining statistical significance of the results). It is therefore appropriate to carry out an in-depth investigation, to test how consistent and useful the findings of the research experience may be in diverse contexts applying adequate control mechanisms.

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